Percutaneous Endoscopic Interlaminar Discectomy for Intracanalicular Disc Herniations at L5–S1 Using a Rigid Working Channel Endoscope

Gun Choi, M.D., Ph.D.
Wooridul Spine Hospital,
Seoul, Korea

Sang-Ho Lee, M.D., Ph.D.
Wooridul Spine Hospital,
Seoul, Korea

Pradyumna Pai Raiturker, M.D.
Wooridul Spine Hospital,
Seoul, Korea

Seungcheol Lee, M.D.
Wooridul Spine Hospital,
Seoul, Korea

Yu-Sik Chae, M.D.
Wooridul Spine Hospital,
Seoul, Korea

Reprint requests:
Gun Choi, M.D.,
Wooridul Spine Hospital,
47-4, Chungdam-Dong,
Gangnam-Gu, Seoul, Korea,
135 100.
Email: choigun@wooridul.co.kr

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OBJECTIVE: Percutaneous endoscopic transforaminal discectomy is often used as a minimally invasive procedure for lumbar disc herniation. However, a transforaminal approach posts limitations at the L5–S1 level owing to anatomic constraints, such as a high iliac crest or small intervertebral foramen and especially for migrated large intracanalicular disc herniations. We discuss the procedure and clinical results of percutaneous endoscopic interlaminar discectomy using a rigid working channel endoscope at the L5–S1 level and the relevant surgical anatomy.

METHODS: We performed percutaneous endoscopic discectomy through the interlaminar approach in 67 patients who satisfied our inclusion criteria during the period from March 2002 to November 2002. All procedures were performed under local anesthesia. Under fluoroscopic guidance, we performed discography using indigocarmine mixed with radio-opaque dye. The 6-mm working channel endoscope was then introduced into the epidural space. Herniated disc material was removed using forceps and laser under clear endoscopic visualization. We retrospectively evaluated the 65 cases with more than 1.5 years of follow-up. The patients were evaluated using the visual analogue scale (VAS) and the Oswestry Disability Index (ODI).

RESULTS: VAS for leg pain (preoperative mean, 7.89; postoperative mean, 1.58) and ODI (preoperative mean, 57.43; postoperative mean, 11.52) showed statistically significant ($P = 0.00$) improvement in their values at the last follow-up examination compared with preoperative scores. Of the study group, 90.8% individuals showed favorable result. The mean hospital stay was 12 hours. The average time to return to work was 6.79 weeks. Complications included two cases of dural injury with cerebrospinal fluid leakage, nine cases of dysesthesia that were transient, and one case of recurrence. Two patients required conversion to open procedure at the initial operation. There was no evidence of infection in any patients.

CONCLUSION: Percutaneous endoscopic interlaminar discectomy is a safe, effective, and minimally invasive procedure for the treatment of intracanalicular disc herniations at the L5–S1 level in properly selected cases, especially when the transforaminal approach is not possible because of anatomic constraints.

KEY WORDS: Disc herniation, Interlaminar approach, L5–S1 level, Minimally invasive spine surgery, Percutaneous endoscopic discectomy

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Performing a lumbar discectomy for a patient with incapacitating sciatica can be one of the most dramatically successful operations in modern medicine. Disc herniation is an unfortunate event that can occur during the natural history of degeneration of all discs. Lumbar discectomy after laminotomy is still considered a gold standard for its treatment (12). To minimize damage to normal tissues while, at the same time, accurately targeting the pathological painful tissue, minimally invasive techniques have been developed for spine surgery, including chemonucleolysis, percutaneous nucle-

otomy, automated nucleotomy, microdiscectomy, transforaminal endoscopic discectomy, or endoscope-assisted discectomy (4, 8, 9, 14–18, 20, 23–25, 29, 30, 32, 34, 37).

With the improvement in optics and rod lens systems, there has been a rapid development of high-resolution endoscopes with working channels, along with a parallel development of applying laser energy and radiofrequency (RF) (Ellman Corp., New York, NY) probes to spine surgery.

Endoscopic surgery has several advantages over open surgery, including clear visualization and targeted fragmentectomy under the guidance of an endoscope and fluoroscope, less damage to the paraspinal muscles and other normal tissues, and the surgery can be done under local anesthesia. Thus, there is reduced patient morbidity with an early return to work. Endoscopic surgery also has a good cosmetic effect. Posterolateral working channel transforaminal endoscopic discectomy is one of the popular endoscopic techniques. The transforaminal approach to the L5–S1 disc space is limited because of the anatomic constraints in certain individuals. A high iliac crest, a large L5 transverse process, a large facet joint or a narrowed disc space and neuroforamen all serve to limit clinical access to the L5–S1 disc space (27, 33).

In such situations, the interlaminar endoscopy for discectomy combines the advantages of posterolateral endoscopy with good visualization of the pathology. We present the technique for the interlaminar uniportal transpinal endoscopic approach with the use of high-resolution rigid working channel endoscope for the L5–S1 disc herniations.

MATERIALS AND METHODS

Between March and November 2002, 67 patients with L5–S1 prolapsed intervertebral discs underwent posterior interlaminar extradural uniportal endoscopic discectomy. The present study emphasizes the surgical technique that was used and retrospectively analyses the clinical results of these cases with a follow-up period of more than 1.5 years.

Inclusion Criteria

Patients included in this study met the following inclusion criteria: 1) unilateral radiating leg pain that was more prevalent than back pain with a positive straight leg-raising test; 2) a trial with conservative modalities for 8 weeks from the onset of pain without any significant relief being achieved; 3) radiological investigations (computed tomographic [CT] and magnetic resonance imaging [MRI] scans) suggesting that a single level central to the posterolateral disc herniation at L5–S1 level correlated with the clinical findings; 4) no previous history of lumbar surgery at the same level; and 5) informed consent was obtained from each patient.

Exclusion Criteria

Patients were excluded from this study based on the following criteria: 1) any associated evidence of central or lateral canal spinal stenosis on the CT and MRI scans with facetal hypertrophy; 2) recurrent disc herniation with adhesions at the same level; 3) severe interlaminar space narrowing; 4) patients with a significant motor neurodeficit; 5) far lateral disc herniations at the L5–S1 level; 6) associated spondylolisthesis; and 7) infection, tumor or fracture associated with the prolapse.

A calcified disc herniation was not a contraindication for the endoscopic surgery. Similarly, upward or downward migrated disc herniations and sequestered disc fragments could be effectively tackled by this approach.

All the patients were interviewed preoperatively for demographic details. The visual analogue scale (VAS) for leg pain, the Oswestry Disability Index (ODI) were used pre- and postoperatively. Macnab criteria (22) were added to those scales.

The anteroposterior and lateral plane radiographs, the MRI and CT scans were evaluated to determine the accessibility of this approach, and the migration of the herniated fragment and also to determine the lesion's relation to the S1 root. The lesions were classified as axillary or shoulder herniations, and the intended trajectory of entry into the canal was calculated. For all the cases, the postoperative MRI scans were examined to establish the treatment plans.

Surgical Technique

After a preoperative dose of prophylactic antibiotic, the patient was positioned on a radiolucent table in an operating theater. The patient could be positioned in either the prone or the lateral decubitus position. The lateral decubitus position with the symptomatic side up was easy and it made handling the endoscope convenient for using the working channel instruments. The lateral position was also supposed to allow gravity to aid the downward displacement of the dural sac and make more room for the passage of the endoscope. The patient was encouraged to take the fetal position with hip and knees bent and the spine flexed to increase the interlaminar space. The lateral position does not lead to any increase in the intra abdominal pressure; thus, it decreased the chances of epidural bleeding. The prone position, on the other hand, may provide better orientation for the spine surgeon.

The procedure was performed under conscious sedation with midazolam (Roche Korea, Seoul, Korea) (3 μg intramuscularly) and fentanyl (Hana Pharm, Seoul, Korea) (50 μg intravenously). Preoperatively, used as a premedication, or during the operation, fentanyl (50 μg intravenously) can be inserted at any time. However, when the patients appeal any pain, the total amount should be less than 500 μg. Continuous feedback from the patient was of utmost importance so as not to damage any neural structure during the procedure. It also helped to monitor the improvement in the clinical symptoms of the patient. One percent lidocaine was used as a local anesthesia.

The image intensifier was set into Fergusson view (a caudal tilt of 15 to 25 degrees), depending on the lumbosacral angulation so that the L5–S1 endplates were parallel. Markings were made on the skin, and the midline was also marked

along the tips of the spinous processes at L5 and S1 with no rotation and with the pedicles lying equidistant from the midline. The medial pedicular line at the S1 vertebral level was marked on the symptomatic side. The superior edge of the first sacral lamina and the inferior edge of the fifth lumbar lamina were visualized to mark the interlaminar space.

The patient was then prepared and draped, and the image intensifier was included in the sterile field. The conventional posterolateral approach was used to perform a discography at L5–S1 under image intensifier control, and diluted 0.8% Indigocarmine (40mgm, 5ml ampoule Carmine, Korean United Pharma, Seoul, Korea) with meglumine ioxitalamate (300mgm/ml Telebrix 30 [Guerbet, France]), which is a radio-opaque dye, and normal saline in a 2:1:2 proportion was instilled intradiscally. Indigocarmine is a vital stain and, as a base, it stains the acidic degenerated nuclear tissue, and helps for the intraoperative distinction of the disc material from the neural elements. The amount of dye mixture used to perform the discography was also important. The discography was performed under the control of the image intensifier, and injection was stopped immediately if the dye was seen to leak epidurally through annular tears. Three–5 cc of dye was normally injected under lateral image control to avoid unnecessary overstaining of the epidural tissues when the dye leaked to epidural area.

The skin entry point was marked under fluoroscopic guidance. In case of the axillary type of disc herniation, the target was the axilla of the S1 root. The skin entry was situated midway between the midline and the medial pedicular line a bit closer to the superior edge of the first sacral lamina on the Fergusson anteroposterior view. On the lateral view, the needle was targeted just below the superior endplate of the first sacral vertebra. The small safe triangular zone for the interlaminar approach was bound medially by the thecal sac, with the S1 root forming the lateral border and the superior edge of the first sacral lamina forming the lower border (*Fig. 1A*). The safest entry was in the lowest portion of this triangle close to the edge of the first sacral lamina. In cases in which the herniation was located just ventral to the nerve root on the shoulder region, there were no spaces for a safety area in the axillar at that time. Therefore, we made a decision to perform the shoulder approach for those cases. On the other hand, those cases usually had a safety area at shoulder region.

In the case of a shoulder-type herniation, the target was the shoulder of the S1 root and the skin entry point was the most lateral area of the interlaminar space (*Fig. 1B*). The skin entry point and the tract were infiltrated with 1% lidocaine. An 18-gauge spinal needle was used to enter the epidural space at the intended site of entry under continuous fluoroscopic monitoring. The epidural space was entered and it gave way after some mild resistance. The position of the needle was confirmed by an epidurogram with using the radio-opaque dye meglumine ioxitalamate (300mgm/ml Telebrix 30). After confirmation, an epidural block was given with 10 cc of plain 1% lidocaine with aspiration to avoid injecting it into blood stream. In cases using the shoulder approach, we did not need preoperative discography. We could insert the needle deeper into the disc space and then achieve the discography after comfracture of the epidural space using the radio-opaque dye. We then waited 5 minutes for the lidocaine to act. A guidewire was then inserted through the spinal needle after removal of the stilet. A 0.7 cm incision was made on the skin over the guidewire, followed by sequential dilatation of the tract. It was important to confirm that the dilators did not fall short of the ligamentum flavum. The dilators then made way for a 6 mm working cannula with a circular opening (*Fig. 2*). These figures show the final positioned working channel under the C-arm. One is for the axillar approach (*Fig. 2A*) and the other is for the shoulder approach image (*Fig. 2B*).

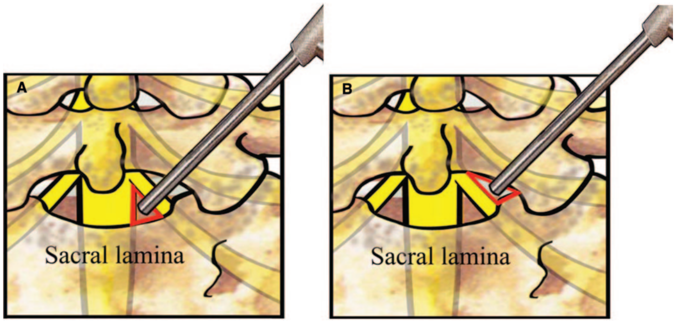

FIGURE 1. *The approaches depend on the location of disc herniation.* A, *axillar approach;* B, *shoulder approach.*

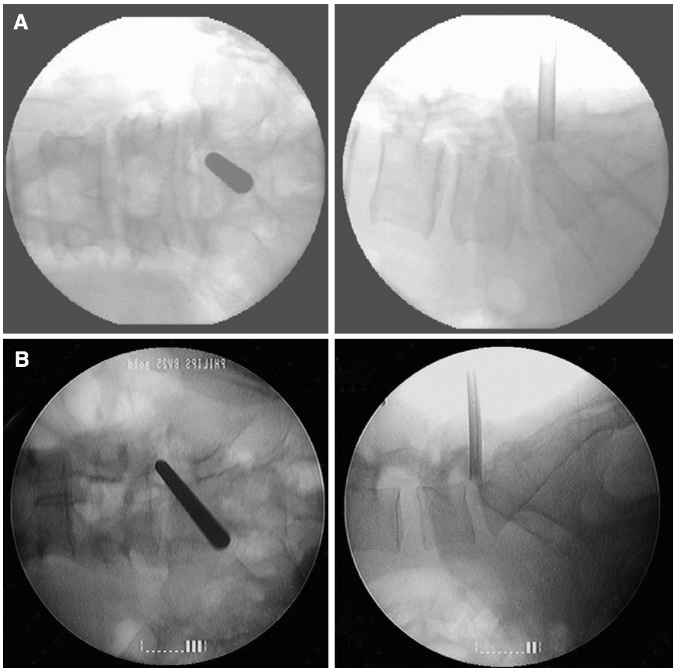

FIGURE 2. *Intraoperative image intensifier images showing the placement of the cannula in the interlaminar window in anteroposterior and lateral views.* A, *axillar;* B, *shoulder.*

The endoscope (YESS; Richard Wolf, GmbH, Knittlingen, Germany) with a continuous inflow of antibiotic instilled normal saline, was then introduced. It was a 20 degree scope with a working channel of 2.7 mm. We proceeded with the identification of various epidural structures. The epidural fat was easy to identify and was the first structure that was usually encountered. It was dissected using the flexible tip of the probe (Triggerflex, Ellman International Inc., Oceanside, NY) that was attached to a high RF generator (Surgitron, Ellman International Inc.). The dural sac and the S1 root were also identified. The herniated tissue could be identified as being blue because of the indigocarmine staining (*Fig. 3*). The protruded posterior longitudinal ligament was seen in the cases of subligamentous herniations. After confirmation of the structures, the blue stained hernia mass was removed using various graspers that were passed through the working channel. Maneuvering the working cannula retracted the neural tissues and thus they were protected, and they were likewise protected by the nerve root retractor. With clear visualization being maintained at all times, all the fragments in the canal were removed. If the posterior longitudinal ligament was intact, it was dissected with the RF flexible probe, a side firing laser probe with Holmium-YAG (Lumenis, Inc., New York, NY) laser and the herniated material was removed.

To enter the disc space from the axillary position, the cannula was levered into the angle between the S1 root and the thecal sac, and was gradually lifted into the disc space. This was only attempted after decompression of the S1 root for the removal of fragments that were extruded. Once lifted into the disc space, as was confirmed by fluoroscopy, the cannula was anchored into the disc space and annulotomy was performed using a trephine. The degenerative disc fragments could be directly removed using the grasping forceps through the working cannula. With the scope passed again into the space, the decompression was assessed and the annulus was modulated using the RF probe and a side firing laser probe with a Holmium-YAG laser. There also might be risks while using the RF modulation and laser probes. There might be heating injury if the RF probe was abused, and laser probes might also cause heating injury. However, both the RF modulation and laser probes were used with cold saline irrigation so that any hearing injury could be prevented and these injuries rarely occurred during the surgery. Also, the penetration of the Holmium-YAG laser probe was less than 0.3 mm. Therefore, the risk of damage was small, and the use of the laser has been approved by the United States Food and Drug Administration. Furthermore, during the operation, RF modulation controlled epidural venous bleeding so that it was useful for visualizing the field. Also, the tip of this probe was so flexible that it could access all the structures and it was useful as to access the whole structure and it is useful for thermal modulation. In addition, the side firing type laser could be used to the ligamentum flavum or the annulus, and it was also required for the thermal modulation for the disc. Therefore, these instruments were considered optional, but the authors feel that they were necessary. The S1 root could be visualized throughout its course to assess the completeness of the decompression (*Fig. 4*). Hemostasis was checked and the scope with the cannula was gradually removed to observe the closure of the ligamentum flavum, which had been only dilated, so it fell back in place. After removal of the scope, a single stitch was done for the skin and a sterile dressing was applied. The patients were discharged either the same day or the next day and were given oral antibiotics.

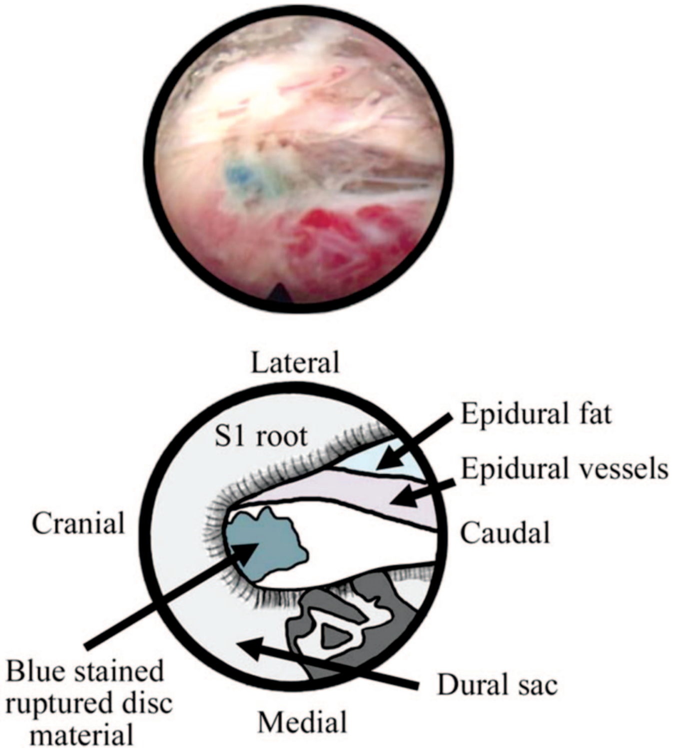

FIGURE 3. *Intraoperative endoscopic view (*top*) and corresponding illustration (*bottom*) showing the axillary placed indigocarmine stained disc herniation.*

Postoperative Outcome Evaluation

Immediate postoperative evaluation included a physical examination with the straight leg raising sign, and a neurological examination to rule out any neural deficit. The patient's VAS assessment for leg pain and back pain were also noted. All the patients underwent a repeat MRI scan on the same day to check for decompression (*Figs. 5* and *6*).

All patients were followed for more than 1.5 years by the researchers over the telephone. The ODI and VAS scores were noted for all patients at the time of the last follow-up examination. The patients with a change in the pre- and post-discectomy VAS for leg pain of more than four points were considered as having an favorable result, and those patients with VAS score difference of three or less were rated as having a poor result.

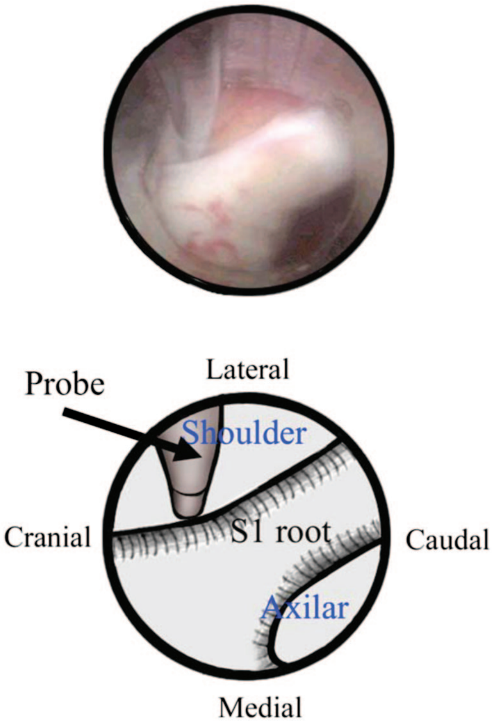

FIGURE 4. *Intraoperative endoscope view (*top*) and corresponding illustration (*bottom*) demonstrating the free S1 root after hernia mass removal. Note the shoulder and axillary portions of the S1 root and the dural sac.*

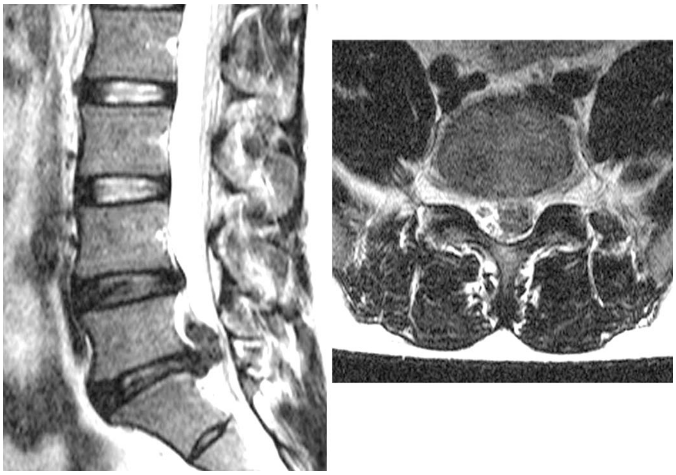

FIGURE 5. *Illustrative case with preoperative MRI scans showing an extruded downward migrated disc herniations at L5–S1 level.*

RESULTS

A total of 67 patients were operated on during the period between March and November 2002 for prolapsed intervertebral disc at the L5–S1 level with the interlaminar endoscopic technique. There were 44 men and 23 women with an average age of 44 years (range, 36–50 yr}. There were two patients who required conversion to an open procedure after abandonment of interlaminar endoscopic discectomy. One of the patients, during the initial part of our learning curve, developed substantial bleeding from the large epidural vessels, and this obscured our vision and made identification of structures difficult. In the other case, the patient was very anxious and uncooperative during the procedure and the procedure had to be stopped for safety reasons. The mean preoperative VAS for leg pain was 7.89 ± 1.01 (range, 6–10), whereas the mean ODI was 57.43 ± 8.72 (range, 34–89). The Macnab criteria were as follows: Excellent, 38; Good, 21; Fair, 4; and Poor, 2 (22). The average duration of symptoms was 4 months (range, 1–13 mo).

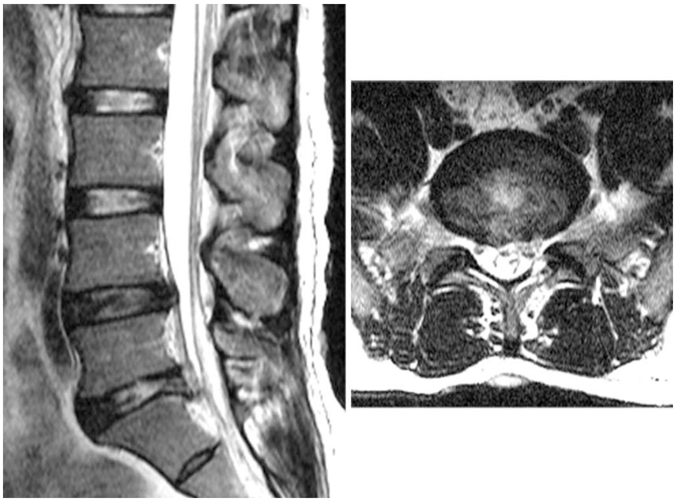

FIGURE 6. *Postoperative MRI scans after interlaminar endoscopic discectomy.*

At the last follow-up examination, after an average period of more than 18 months postoperatively, the mean VAS for leg pain was 1.58 ± 1.96 (range, 0–7), whereas the mean ODI improved to 11.52 ± 7.7 (range, 2–40). The improvement in the VAS for leg pain and the ODI was statistically significant (P = 0.00) (*Fig. 7*).

Fifty-nine patients (90.8%) showed excellent to good results at the end of the last follow-up period, whereas the remaining

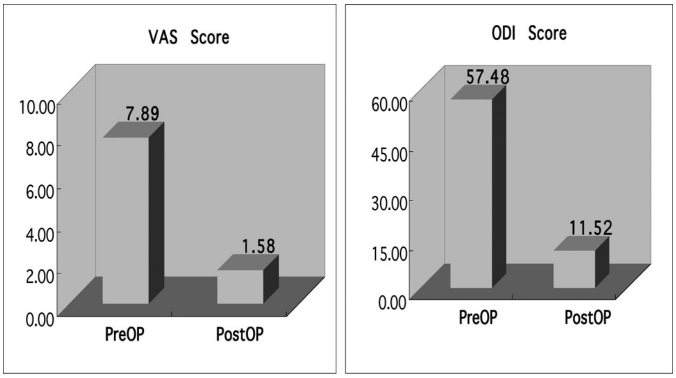

FIGURE 7. *Comparison of pre- and postoperative VAS and ODI scores.*

six patients (9.2%) had a fair outcome. The mean hospital stay was 12 hours (range, 4–48 h) and the average period before a return to work was 6.79 weeks (range, 1–48 wk).

There were two cases of injury to the thecal sac with cerebrospinal fluid (CSF) leakage and damage to the nerve rootlets while we were using forceps for disc removal. There was no significant neurodeficit, but some sensory hypesthesia in the leg was noted on the detailed physical examination. However, the patient's preoperative radicular pain had improved. The CSF leakage was minimal, did not require open repair, and was managed by increasing the patient's hydration. The patient required admission for observation for a couple of days.

Nine patients (12%) developed dysesthesia in the leg in a dermatomal distribution, and this was different than the preoperative shooting radicular pain. Three of these patients required epidural steroids and the rest were managed with oral gabapentin. All the dysesthesia was transient and improved over 1 month.

The MRI results were as follows: 60 patients had near total disc removal. Residual disc was shown in five patients. One patient had repeat interlaminar surgery performed at the index level contralateral side because of free fragment moved to the contralateral side with producing sciatica the next day and the other patients with residual discs showed improved symptoms. However, only one of them required open surgery 2 months later and the rest showed improvement at the last follow-up examination.

One patient developed recurrent herniations on the same side. He was managed with open lumbar microdiscectomy and obtained a successful result. There were no cases of neural deficit or infection, and none of the patients experienced disability or were unable to return to work. Furthermore, there was no instability that developed at the time of the last follow-up examination.

Two patients showed insignificant residual back pain with a VAS score of four, and two patients showed significant leg pain with a poor outcome. Two patients required narcotic analgesic medication at the last follow-up examination.

DISCUSSION

The success rates of discectomy for the treatment of lumbar disc herniation range from 80 to 96% (26). The outcome of lumbar discectomy does not seem to be affected by use of microscope, and the outcome depends on patient selection, rather than on the surgical technique (26). As a corollary, in properly selected cases, endoscopic surgery could be one option, and this technique decreases patient morbidity with minimal damage to the normal tissues.

Percutaneous transforaminal endoscopic techniques for the treatment of lumbar disc herniations, with using the principles of targeted fragmentectomy under local anesthesia with the guidance of a fluoroscope and clear visualization by an endoscope, have evolved over the past 3 decades. Kambin et al. (15–20), Schreiber et al. (35), and Yeung and Tsou (37) have improved on the percutaneous nucleotomy technique with the introduction of endoscopes, popularizing arthroscopic discectomy. With the introduction of high resolution working channel endoscopes, lasers, and RF bipolar flexible probes, the technique is now more versatile.

Ebraheim et al. (10) have analyzed the location of the extraforaminal lumbar nerve roots in relation to the intertransverse space by performing cadaveric dissection, and they found that the intertransverse space was the narrowest at the L5–S1 level (average, 13.4 mm ± 4.1 mm) compared with an average of 24mm ± 3mm at all the other lumbar intertransverse spaces. Reulen et al. (33) further described the peculiarities at the L5–S1 space for the lateral approach with the facets joint at that level overlapping the disc space cephalocaudally and laterally. The isthmus at L5 lamina also extends more laterally and at times it also overlaps the waist of the vertebral body. The transverse process at the L5 level originates at a lower level from the body and it is broader with a bend, which is occasionally inferiorly directed. All these peculiarities hinder the posterolateral access to the L5–S1 disc space.

There have been many innovations to overcome these problems. The curved needle technique for discography or chemonucleolysis or the curved cannula used for the automated percutaneous lumbar discectomy has been developed to avoid such anatomic constraints (30). There has also been development of curved cannulas with flexible endoscopes, and attempt have been made at the transiliac endoscopic approach to the L5–S1 space (9, 31).

In the case of L5–S1 foraminal stenosis, percutaneous endoscopic lumbar discectomy can be used. Ahn et al. (1) described posterolateral percutaneous endoscopic foraminotomy for L5–S1 foraminal or lateral exit zone stenosis in selected cases, and they obtained good results. This procedure was done for extraforaminal stenosis at this level with the removal of the superior articular process by using a bone reamer and a side firing laser probe.

Zahiri et al. (38) described a method for accessing the L5–S1 disc space using certain bony landmarks and marking their topographic reflection on the lumbar spine to calculate the caudal and axial angle of entry. Knight et al. (21) have also described the use of a jig for marking the exact entry point for access to the L5–S1 disc space.

Although it may be possible to pass the needle and the working cannula into the foramen, it is difficult and demanding to access the disc in its entirety and to access the epidural space with the routine working instruments owing to the working trajectory. Thus, the current posterolateral approach for the L5–S1 disc space is relatively difficult because the iliac wing prevents access of the instrumentation into the plane of the disc and, thus, the ability to explore the spinal canal is very limited. This technique's application to migrated, sequestered or large and centrally located disc herniations is not reproducible in all cases or by all surgeons in our opinion.

The lamina of the lumbar vertebrae can be totally confined to the vertical limits of the vertebral body or conversely, the inferior margin of the lamina can overhang the disc space in the anteroposterior projection. Ebraheim et al. (11) investi-

gated the position of the intervertebral disc in cavaders as being projected on the posterior aspect of the lumbar spine. The distance between the superior margin of the first sacral lamina and the superior endplate of the L5–S1 disc was consistently an average of 13.9 mm (range, 10.5–19.0 cm), whereas the distance between the inferior margin of the L5 lamina and the inferior endplate of the L5 vertebra varied between -3.0 mm and 8.5 mm. Thus, there was some overhang, but it was less than that seen in the upper lumbar vertebrae. The interlaminar distance was greatest at L5–S1 level and the width of the interlaminar space was also a maximum at 31 mm (range, 21–40 mm).

Another peculiar aspect of the anatomy of the L5 lamina is that, in the coronal plane, it is not directed vertically as the upper lumbar laminae, and it has a backward and downward angulation to the vertical axis. The anatomic feature helps to access the interlaminar space of the spinal canal at the L5–S1 level if the trajectory of needle is 5 to 10 degree caudal-cranial direction. The spinal canal at the level of the L5–S1 contains the thecal sac with the sacral roots only and so the proportion of free space at the L5–S1 level is also greater.

The nerve roots emerge from the thecal sac at different levels depending on the involved vertebral level. The caudad nerve roots, including the S1 nerve root, show a relatively cephalad exit from the thecal sac as compared to the upper lumbar levels. The S1 nerve root exit is at the level of the L5–S1 disc space. The S1 root is the traversing root at the L5–S1 disc space, but, contrary to the other levels at the L5–S1 disc space, the S1 root is already separated from the thecal sac. The S1 root has a very short intraspinal course as the S1 root dorsal root ganglion is intraspinally situated.

The S1 nerve root take off angle is on an average 22 degrees (range, 18–26) (6, 13), and it is possible to gain access to the herniations in the axilla of the S1 root within this angle.

In case of a posterolateral herniated L5–S1 disc, the nerve root that is usually affected is the S1 root; because of the mass effects, the root is displaced and this creates more space for entry. In most cases, the prolapse is axillary in location and this increases the root thecal sac angle and creates more space for the passage of the cannula without damaging the root. For a prolapsed disc situated at the shoulder region, the root is displaced downward medially and so the cannula can be easily maneuvered at the shoulder region.

The ligamentum flavum is thinnest at the L5–S1 interspace and its average thickness varies from 2 to 6 mm, but its thickness is affected by the age of the individual, the associated degenerative changes, and the position of the spine during flexion or extension. The ligamentum flavum forms a tented recess with the apex in the midline and just inferior to the inferior edge of the cephalad lamina. The depth of this recess up to the dura measures 3 to 4 mm, and is occupied by the epidural fat (28). This depth may be partly obliterated in case of a prolapsed disc in the canal. It is this recess that forms the working space for interlaminar endoscopy upon entry.

The dimensions of the interlaminar space at the L5–S1 level make it possible to work in the closed compartment bound by the ligamentum flavum and inside the spinal canal without injury to the thecal sac and the S1 nerve root.

The placement of the initial guide wire and the cannula are most crucial factors to prevent injury to the neural tissues. Meticulous planning for the trajectory of entry by locating the herniated fragment in relation to the S1 nerve root needs to be done.

Since the S1 root emerges from the thecal sac at the level of the L5–S1 disc in most patients, directly accessing the disc space from the posterior aspect can damage the S1 root. We performed serial dilatation over the guidewire by using dilators starting from 1 to 6 mm in diameter. This ensures that the axillary entry is gradually dilated and this prevents laster neural injury by the cannula later. The entry is made into the canal in the axillary or shoulder region of the S1 root depends on the location of the herniation.

For the technique of interlaminar endoscopy, the working sheath is in the epidural space, and it is in the axilla of the S1 root for axillary herniations and in the shoulder in the case of shoulder herniations. The next important step is the identifying all the visualized structures. Indigocarmine is used for discography before the herniated degenerate nuclear tissue is stained blue, so it is easy to differentiate this diseases tissue from the neural tissue. Once all the anatomy is identified and the fragment removed, the cannula can then be easily levered into the disc space to search for any residual fragments in the disc space. An upward or downward migrated fragment or a sequestrated fragment can be easily tackled by this approach by placing the cannula appropriately in the safe zones. To assess the completeness of the decompression, the S1 root can then be visualized in its entire course.

The ligamentum flavum constitutes an active ligament that has an essential biomechanical role, and any injury to it is probably not without consequences. The problem of peridural fibrosis is the direct consequence of intrusion into the spinal canal with a break of this effective barrier. Peridural fibrosis results from the migration of fibroblasts that are derived from dedifferentiation of overlying detached muscle and that have gained access to the spinal canal (3). There have been reports of open discectomy with the preservation of the ligamentum flavum, and these cases have comparable long-term results with a reduced complication rate (2, 36). The original anatomic planes were preserved with this method. We penetrated the ligamentum flavum with a needle and the opening in the ligamentum was made with sequential dilatation by using blunt cannulas: thus, there was separation of the fibers in all the layers of the ligament rather than excision. This ensured that, once the endoscope is withdrawn, the opening in the ligamentum closes with approximation of the fibers. This may help to restore the barrier between the epidural space and overlying muscular tissues, and this decreases the chances of peridural fibrosis and scarring. Also, if surgery is required later, identification of the anatomic plane is easier.

Choy (5) described a posterior extrathecal needle approach to the L5–S1 disc space as being safe and simple for percuta-

neous laser disc decompression instead of the transforaminal approach, especially for patients with a high iliac crest.

De Antoni et al. (7) have performed translaminar lumbar epidural endoscopy as an alternative to the posterolateral endoscopy for the L5–S1 level by using standard arthroscopic instrumentation with triangulation. They performed the surgery through a working portal using standard instruments, and visualization was achieved through another cannula with a standard 30-degree arthroscope placement. After removal of the extruded fragments, they recommended discoscopy for examining and removing any intradiscal material. They reported good results compared with other minimally invasive operations on the spine, and they viewed the procedure as complimentary to the posterolateral endoscopic approaches.

Chiu et al. (4) performed extradural transpinal percutaneous discectomies for L5–S1 disc herniations by using a working channel endoscope, and he obtained some promising results. In his technique, the needle is always introduced at the most lateral point of the interlaminar space over the shoulder of the root and directly into the L5–S1 disc space, and this is irrespective of the location of the herniation. In such a situation, we think it may be difficult to access the axillary herniated disc. In the present technique, we altered the point of needle insertion depending on the location of the herniation and its relation to the S1 nerve root. During the preoperative planning with the radiological data, we decided to perform an axillar or shoulder approach to place the needle and cannula in a safe area.

However, if there are no safe spaces in either the shoulder and axillar regions on the radiological findings, we have to consider performing an open microdiscectomy. Although it is soft disc herniation, if the interlaminar space is narrow or if there might be no available safe space because of the nervous system within the canal, there may be the risk of nerve damage or dysesthesia. Therefore, this technique is not considered universal. We did not evaluate the accessibility personally, but we estimate that fewer than 20% of L5–S1 disc herniation cases cannot be approached transforminally. But, this depends on the surgeon's preferences. We prefer an interlaminar approach if the patient can be treated by both transforaminal and interlaminar approaches.

Interlaminar endoscopy is performed under local anesthesia with the patient consciously sedated, thus decreasing the morbidity of general anesthesia. This is appropriate for patients who are high risk for general anesthesia because of their associated medical problems. This endoscopic technique can be performed on an outpatient basis with a decreased hospital stay and less expense. Using just a 0.5 cm incision, the procedure achieves a good cosmetic result.

With the surgeon's continuous interaction with the patient, there is a high safety factor for preventing neural damage during the introduction of the working sheath. The two cases of neural injury in the present study occurred during the initial part of our learning curve. These injuries occurred while disc removal was attempted in the presence of dural adherence to the posterior longitudinal ligament, which was not recognized preoperatively. With continuous irrigation and egress of an antibiotic instilled normal saline solution, there is minimal risk of discitis.

Nevertheless, there might be risk for performing a discography. Discitis, on rare occasions, could be a problem. However, if the dye and indigocarmine were maintained as sterile, this should not be a significant problem. Despite this risk, discography enabled the surgeons to distinguish the proper site for the surgery because it stains the herniated disc blue, and also shows whether there was leakage. Thus, it was considered necessary. There is a possibility of dysesthesia occurring owing to retraction of the nerve root by the operating cannula during the procedure, as well as the possibility of thermal injury owing to the use of laser in the vicinity of the root, depending on the individual condition. We consider that retraction should be gently performed with great care and that the laser should be used with enough space to prevent dysesthesia.

The disadvantages of this technique are the steeper learning curve, the use of expensive equipment, and the radiation exposure to the operator and the patient. Furthermore, in the case of learning curve, any surgeon capable of undertaking microdiscectomy without difficulties in ordinary times can perform this surgery. However, at least the initial 10 cases require the supervision of an experienced surgeon. Surgeons should be oriented with the endoscope, and with all the necessary directions concerning the use of the various implements such as forceps, laser probe, and RF probe, in addition to the appropriate time for their use. Also, in terms of potential risks and dangers, it is thought that these techniques are very safe only when the surgery is performed slowly and gradually to remove any target. Even when nerve injury occurs, there might be an immediate reaction owing to the patients' conscious sense of pain.

In the case of epidural block, if 20% lidocaine is used, the neural tissue might undergo complete anesthesia. Thus, the surgeons could not know if there is any neural injury owing to the lack of feedback from the patients. Hence, approximately 10 cc of 1% lidocaine is recommended to prevent complete anesthesia, so that patients can react before nerve damage, enabling surgeons to avoid nerve damage.

CONCLUSION

Posterior endoscopic interlaminar discectomy is a safe and effective procedure for intracanalicular disc herniations at the L5–S1 level. It is a direct approach for the disc herniations with the preservation of normal anatomy. In this study, we have shown the clinical efficacy of this procedure and the results are comparable to the results of other techniques of disc herniation.

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COMMENTS

Choi et al. have reported relatively good clinical results among 67 patients treated with percutaneous endoscopic interlaminar discectomy at L5-S1 using a working channel endoscope. The L5-S1 level is probably the only lumbar level amenable to this approach because of its wide interlaminar space. The shingled orientation of the adjacent laminae would preclude the use of this technique at the other lumbar levels.

The authors' experience and skills with this technology for other applications (i.e., percutaneous posterolateral endoscopic discectomy) has an important favorable impact on his clinical results. The use of laser probes, radiofrequency thermal modulation, discography, and a small working channel endoscope have definite risks and a unique learning curve that need to be appreciated and mastered by surgeons prior to clinical utilization of these techniques. Surgeons who are novices at percutaneous spinal endoscopic discectomy with a working channel endoscope should be cautious in implementing this approach in order to avoid mechanical nerve injury, thermal nerve injury, CSF leak, or inadequate disc resection.

There are several major limitations of this percutaneous endoscopic approach with a single working channel endoscope. The single working channel does not allow for bimanual dissection and retraction of the nerves to protect them from injury during the dissection. In addition, the visualization is limited to the field of view directly in front of the tip of the endoscope; the surgeon is blinded to any structures that are adjacent to the shaft of the endoscope. The risk of nerve injury, cauda equina injury, or durotomy is likely to be much higher than these risks for open microdiscectomy.

Open microdiscectomy, whether it is performed with conventional

retractors or tubular retractors, remains the gold standard for surgical treatment of herniated lumbar discs. Open microdiscectomy unequivocally provides superior capabilities to perform a laminotomy, to retract and protect the nerves, to visualize the nerves and cauda equina intraoperatively, and to completely resect herniated lumbar discs.

Curtis A. Dickman
Phoenix, Arizona

Choi et al. report on an interlaminar approach to discectomy for disc herniations at L5/S1. They have accumulated a wide experience and clearly are doing well with this procedure. Their technique enables discectomy using this technology at a level which previously has been quite difficult secondary to the anatomy of the transforaminal approach at L5/S1. However, this technique has required several additional steps which typically are unnecessary, such as indigo carmine staining and discography. Even with these additions, the temporary and permanent complication rate seems higher than seen with open microdiscectomy or endoscopic discectomy via a tubular retractor. Thus, when compared to the "gold standard," the complication rate of this minimally invasive technique might be unacceptably high. That being said, however, if further development of this technique can decrease the complication rate to acceptable levels, it does seem interesting and potentially applicable.

Richard G. Fessler
Chicago, Illinois

This paper describes a case series of patients treated with an endoscopic discectomy technique. The authors followed their patients for 12–18 months, and approximately 90% of patients enjoyed good outcomes as measured by the Oswestry and the VAS. The technique described by the authors appears to be a minor modification of that previously described by De Antoni and Chiu. The novel aspects of this technique include the inter-laminar approach, which is most relevant at the L5-S1 level where a transforaminal approach may not be possible due to the position of the ileum, and the methods used to target the cannula. While no evidence is presented to suggest that this technique is better than or worse than any other technique used to treat patients with radiculopathy, the technique does appear to be safe and effective for the operative treatment of radiculopathy in a select group of patients.

Daniel K. Resnick
Madison, Wisconsin

The authors provide us with some insights into their technique for true endoscopic treatment of L5/S1 disc herniations. Their impressive series of 65 patients experienced very acceptable clinical outcomes, attesting to their significant experience with this approach. Of particular note, the authors routinely perform an intra-operative discogram with indigocarmine to help them localize the ligamentous and annular tears endoscopically. This technique has helped them perform complete fragmentectomies and may be part of the reason they had a low re-herniation rate. In addition, the authors use the stain to differentiate between the connective tissues and dura, reducing the very substantial rate of nerve root injury during endoscopic discectomy. Nonetheless, endoscopic spinal surgery remains technically challenging, and the authors should be commended for their excellent results.

Michael Y. Wang
Los Angeles, California